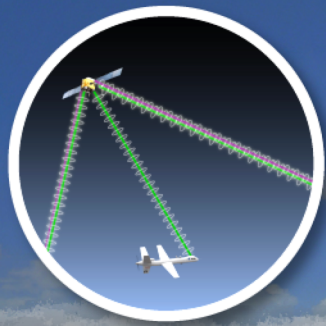




Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

Automatic Execution of Collision Avoidance
and Return to Course Analysis (D.6.20)

Experiment Review





Background

- Phase 1 of UAS DAA MOPS included Class I and Class II DAA systems
 - Class I – DAA-only (i.e., no collision avoidance)
 - Class II – DAA + TCAS II
- Phase 2 introduces Class III DAA systems
 - ACAS Xu provides both DAA and CA functionality
 - Minor modifications made for DAA
 - No DAA Warning
 - No Well Clear Recovery Guidance
- There is a need to develop Resolution Advisory (RA) display requirements for ACAS Xu
 - DAA requirements leveraged from the Phase 1 DAA MOPS
 - Vertical RA display guidance informed by TCAS
- Current gaps in display requirements:
 - How are horizontal and “blended” RAs presented?
 - How should automated ACAS functions be presented and behave?



Experiment Objective

- The engineering analysis will generate “canned” RAs rather than use Xu code, divided into two parts.
- Part 1 objectives:
 - Investigate the effects of various display configurations on pilot response to ACAS Xu RAs
 - Get pilot feedback on display and alerting guidance for ACAS Xu
 - Verify differential effects of RA alerting configurations
 - Inform design for ACAS Xu full mission HITL
- Part 2 objectives:
 - Investigate the effects of automating collision avoidance (CA) and return-to-course (RTC).
 - Use findings to inform optional automation requirements for SC-228
 - Examine pilot response to apparent automation failures



ACAS XU ENGINEERING ANALYSIS PART 1 OVERVIEW



Part 1 Experimental Design

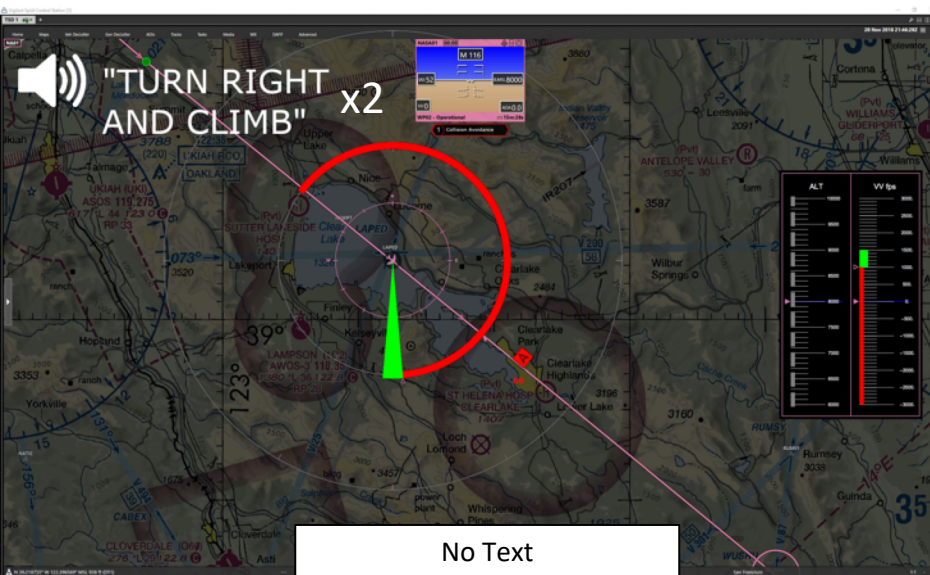
- Independent Variables (2-by-2, within-subjects)
 - Text (2 levels)
 - Text guidance provided
 - Text guidance absent
 - Blended-offset alerting (2 levels)
 - Basic aural alerts
 - Advanced aural alerts
 - Embedded Variable (within-trial)
 - RA type*
 - Vertical-only
 - Horizontal-only
 - Blended-simultaneous
 - Blended-offset
- } Unique RAs to ACAS X

*Note: to simplify our design we have not included RA reversal, strengthening, or multi-threat encounters. These cases may be examined in a upcoming study by the FAA.



Part 1 Experimental Design: Text IV Example

- Blended-simultaneous RA





Part 1 Experimental Design: Blended-Offset Alert IV Example

- Advanced behavior for blended-offset RAs
 - First RA issued normally (e.g., as a vertical or horizontal RA)
 - “Climb/Descend” x2
 - “Turn Right/Left” x2
 - Logic used to modify order and verbiage of second RA
- Example: Turn right RA followed 8 seconds later by climb RA
 - **Basic** aural alert:
 - First aural alert: “Turn Right” x2
 - Second aural alert: “Turn Right and Climb” x2
 - **Advanced** aural alert:
 - First aural alert: “Turn Right” x2
 - Second aural alert:
 - If target heading not achieved: “Climb and Turn Right” x2
 - If target heading achieved: “Climb and Maintain Heading” x2



Part 1 Experimental Design

- Dependent Variables
 - Response Time to RAs
 - Do they vary by RA type?
 - Do they vary by RA presentation?
 - Compliance rate
 - Did the RA display affect the participants' ability to successfully comply with RAs?
 - Diagnose instances of non-compliance
 - Subjective ratings
 - Workload (NASA TLX)
 - Post-Trial & Post-Sim Questionnaires
 - Post-Sim Debrief (open-ended)

Note: not assessing Loss of Well Clear/NMAC performance since we're scripting RAs and constraining their responses to DAA alerts.



Part 1 Hypotheses

- Research Question
 - How does the absence or presence of textual RA alerts affect pilot response to ACAS Xu advisories?
 - Can pilots comply with blended RAs with comparable performance to single-sense RAs?
 - Is performance affected by blended-offset alert variable?
- Expected Outcome
 - The presence of textual alerts will increase pilot accuracy in compliance with ACAS Xu RAs, particularly for blended RAs.
 - Pilots will be slower to respond to blended RAs.



ACAS XU ENGINEERING ANALYSIS PART 2 OVERVIEW



Part 2 Experimental Design

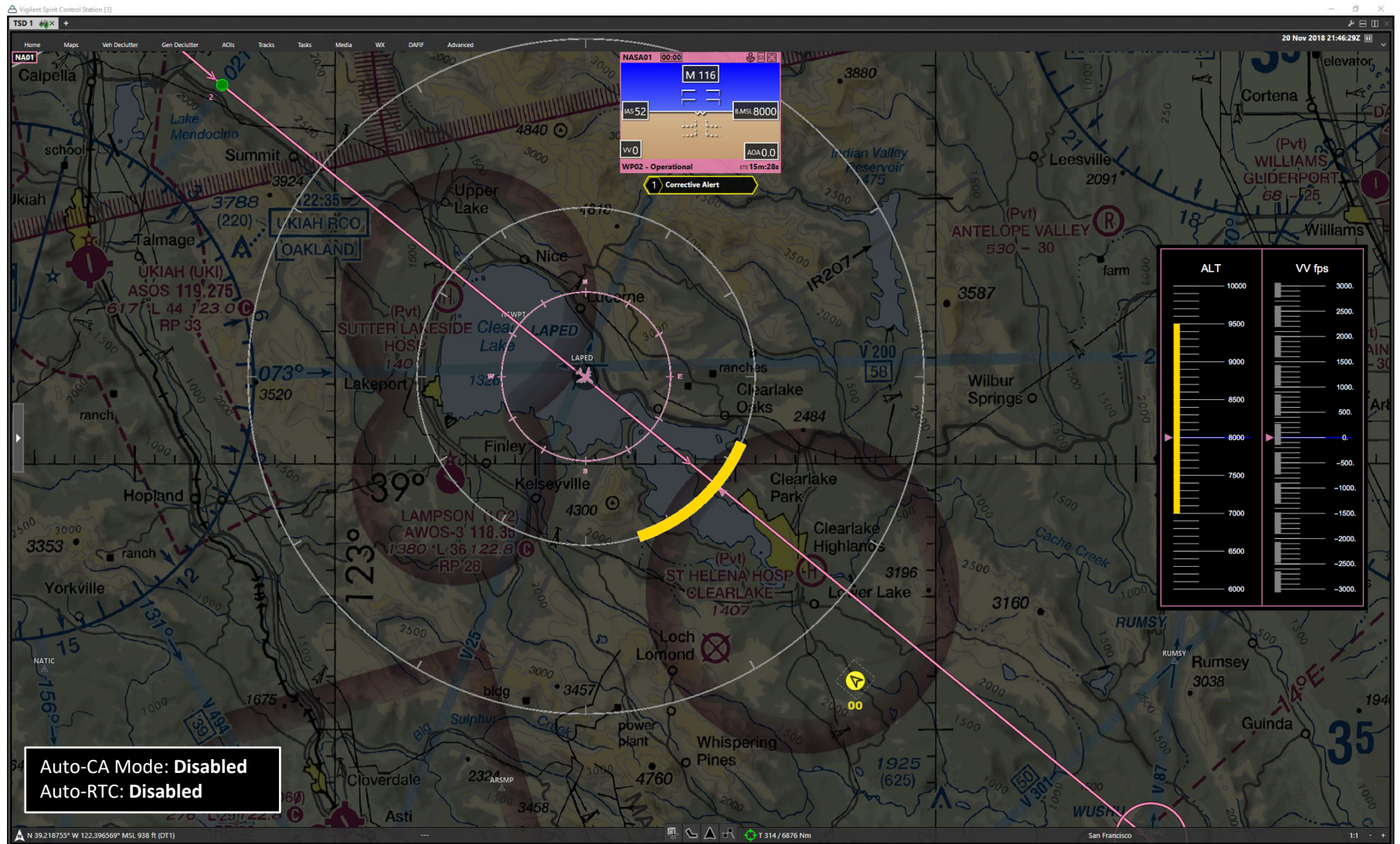
- Independent Variables
 - Automation Level (within-subjects, 3 levels)
 - Manual
 - Carries over preferred display (per pilot feedback) from Part 1
 - Auto Collision Avoidance (CA)
 - RA is auto-executed as soon as issued
 - Pilot can disengage (override) automation at discretion
 - Auto CA & Return-To-Course (RTC)
 - RTC is auto-executed as soon as Clear of Conflict (CoC) is declared
 - Pilot can disengage (override) automation at discretion
- Embedded Variable (within-trial)
 - RA type
 - Vertical-only
 - Horizontal-only
 - Blended-simultaneous
 - Blended -offset
 - Automation failure
 - Auto CA response fails to occur



MANUAL CA & RTC EXAMPLE

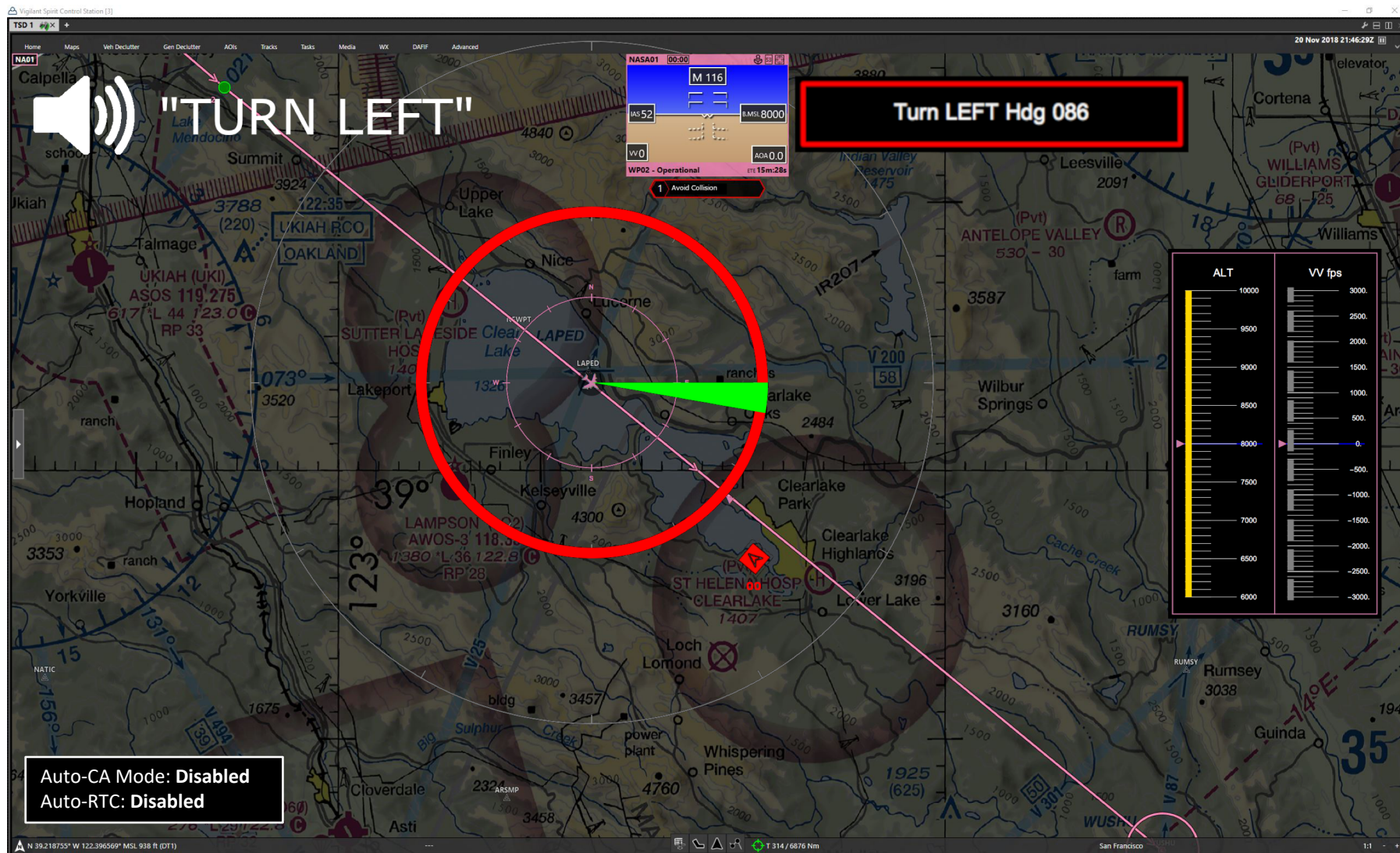


Manual – Prior to RA



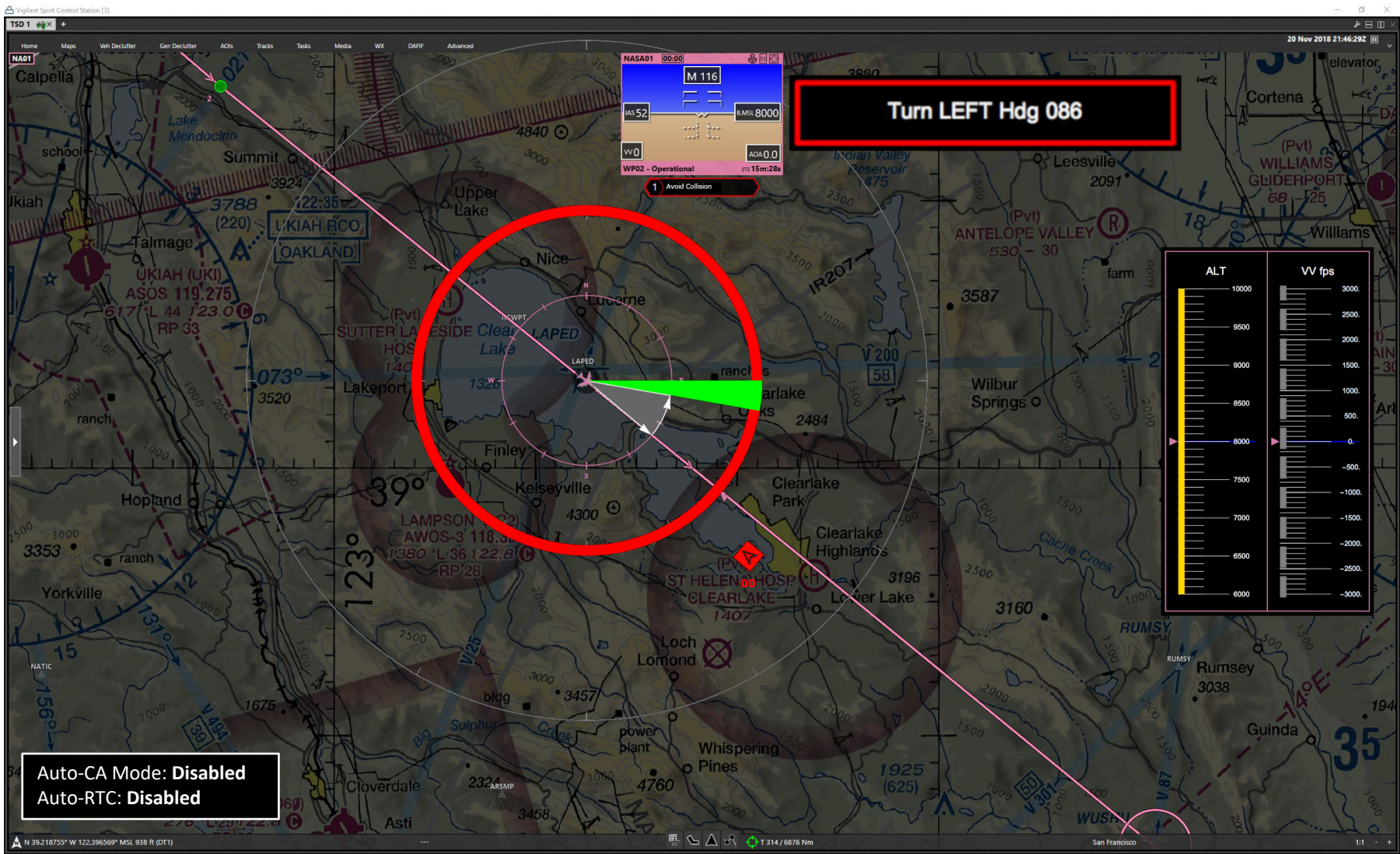


Manual – Horizontal RA Issued



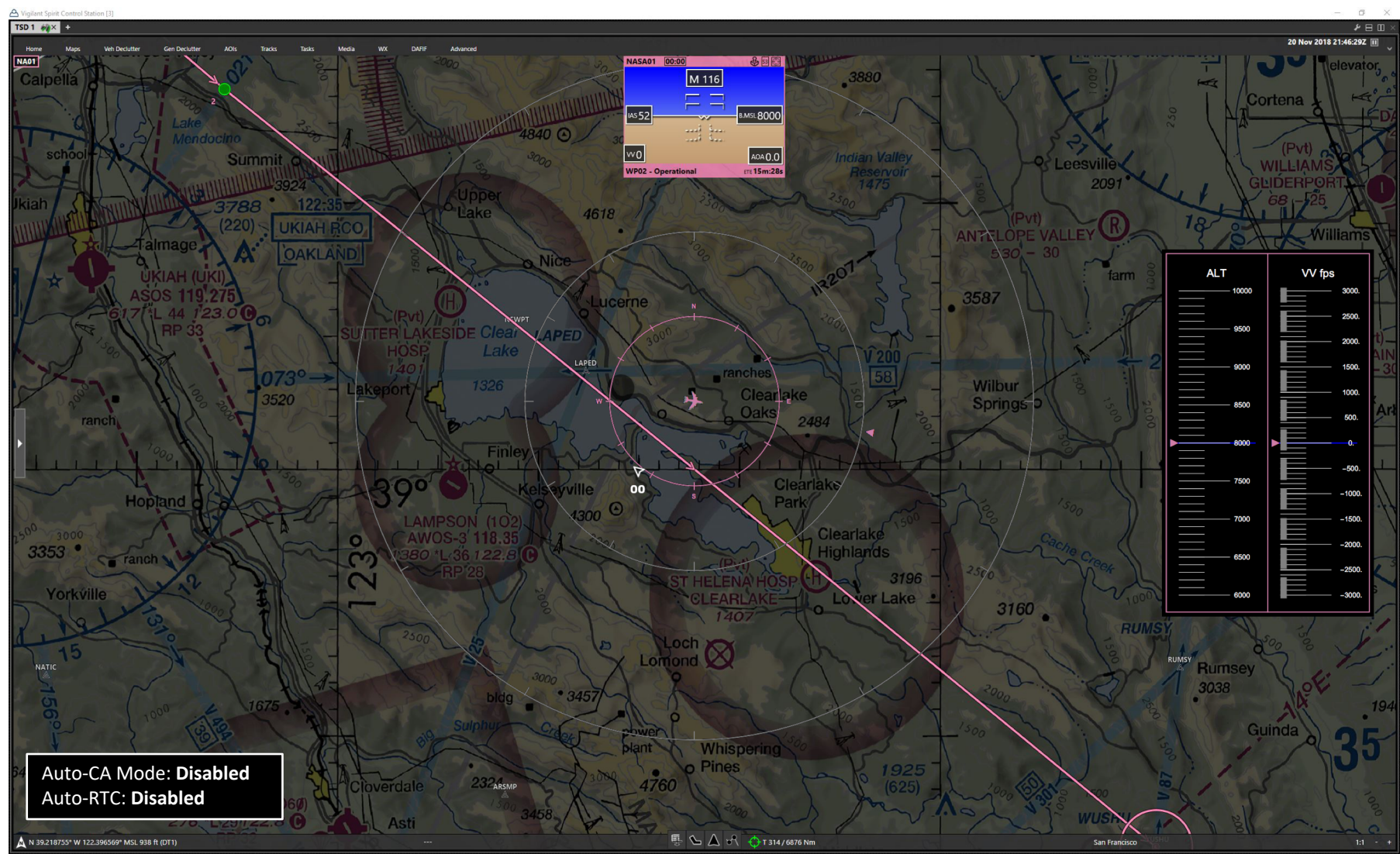


Manual – PIC Modifying Heading



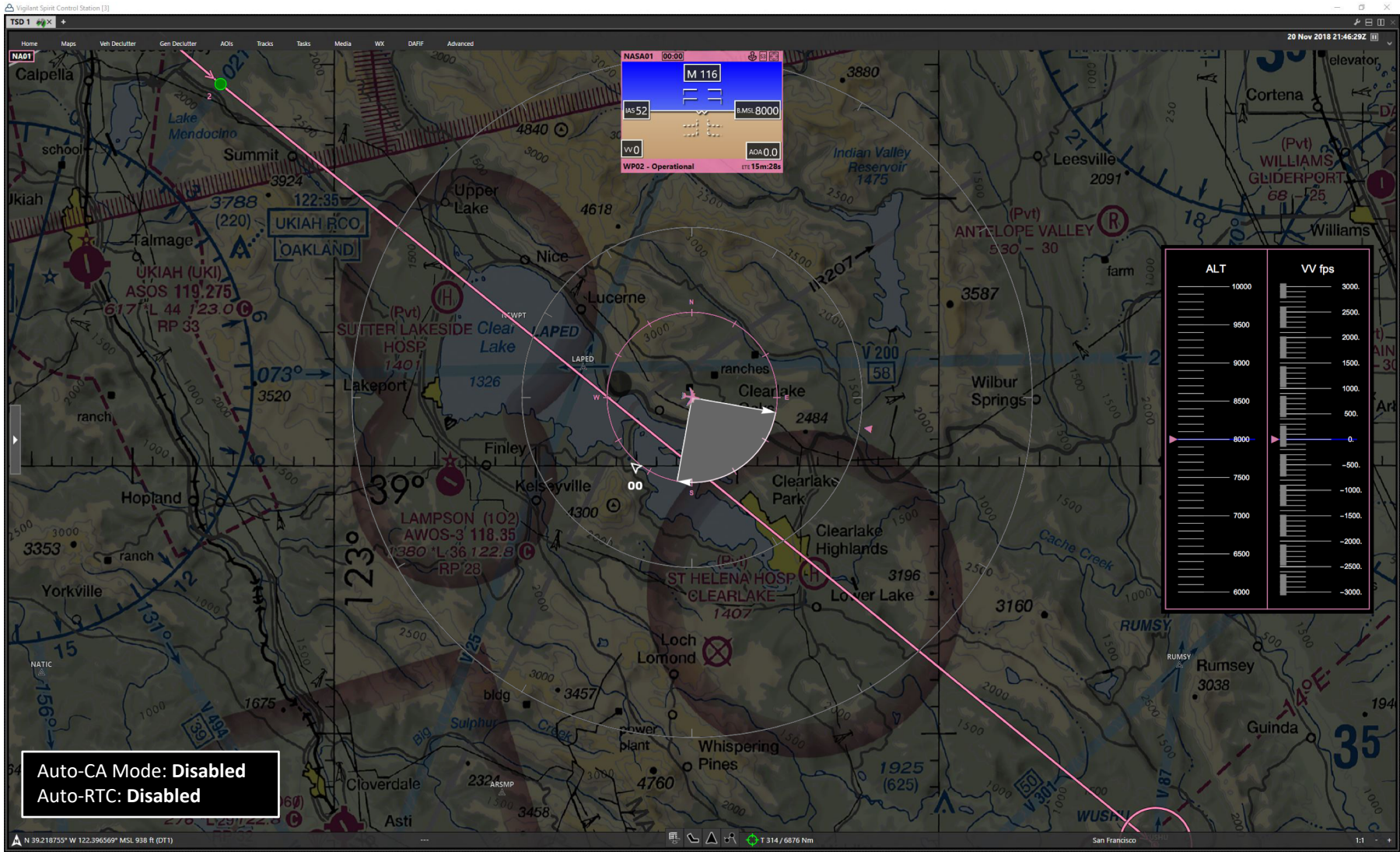


Manual – Clear of Conflict





Manual – PIC Performs RTC

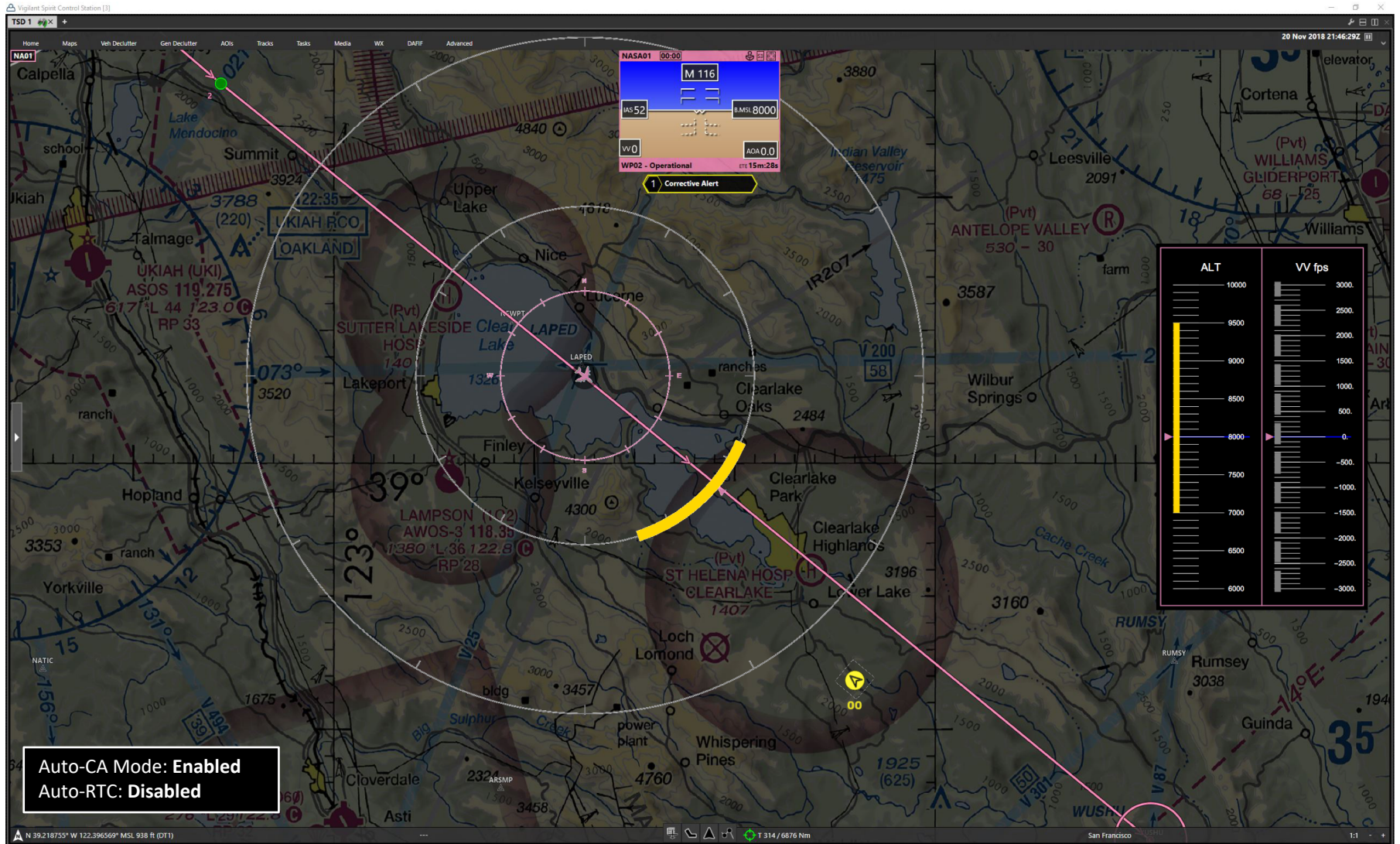


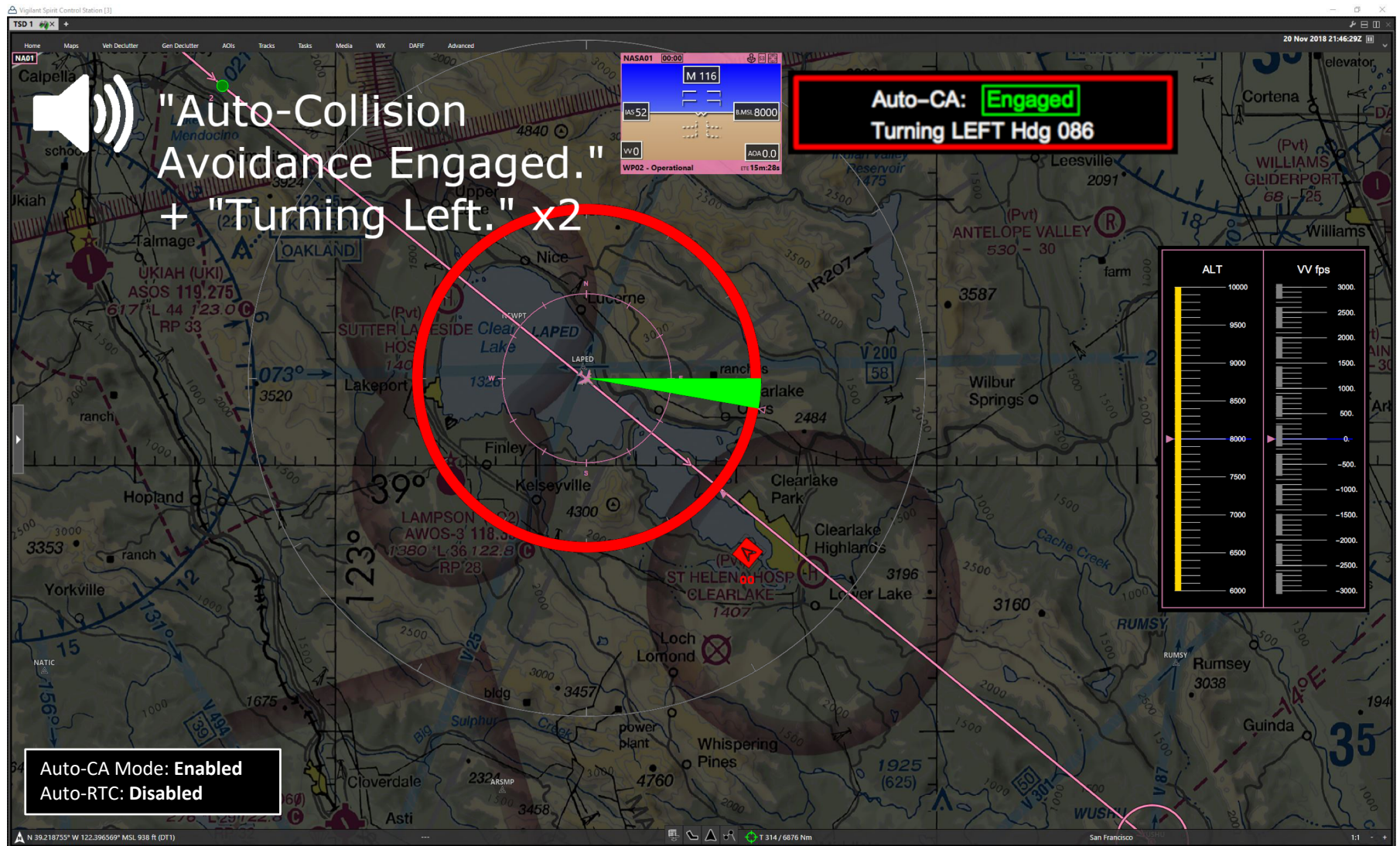


AUTO CA & MANUAL RTC EXAMPLE



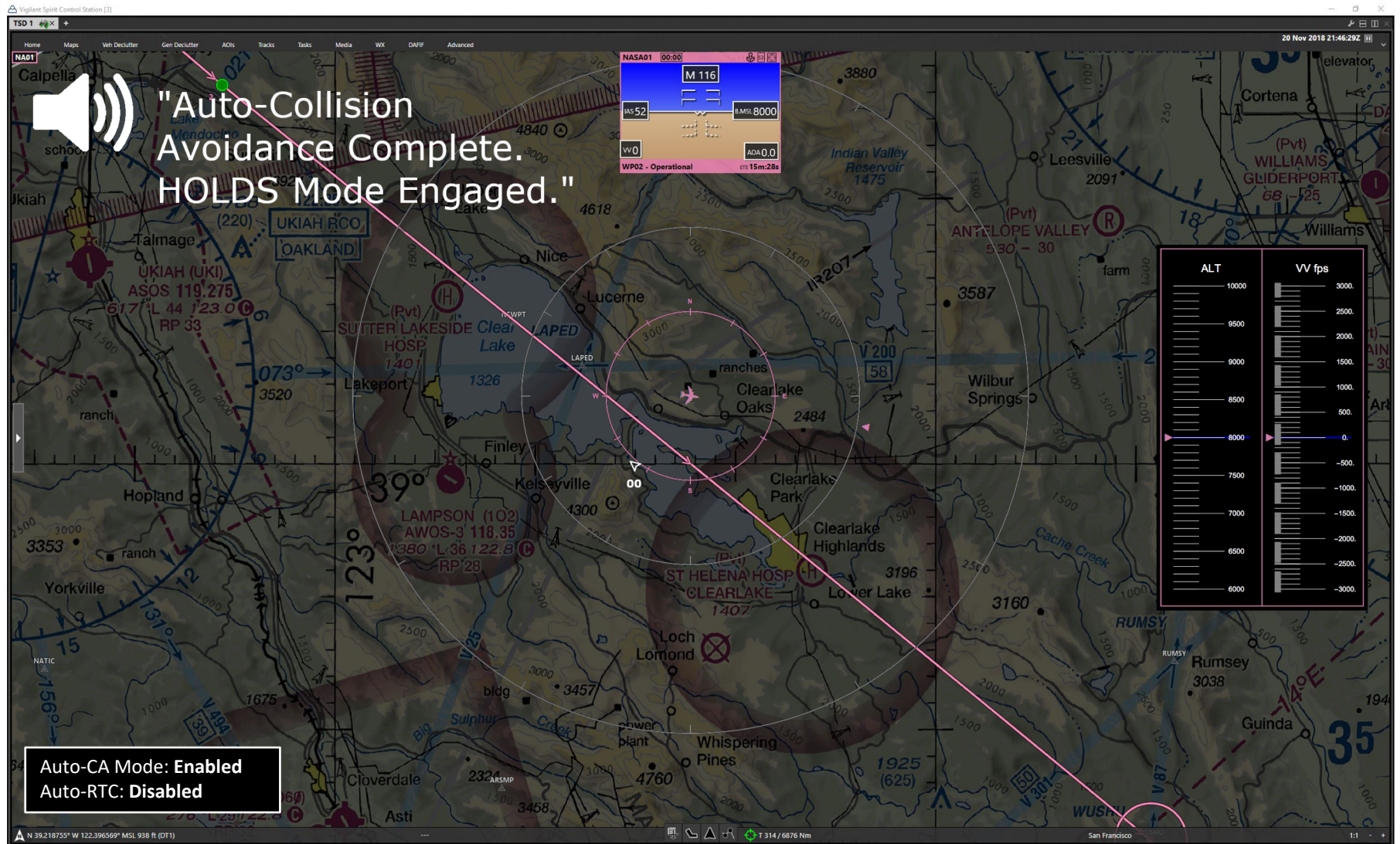
Auto CA Only – Prior to RA





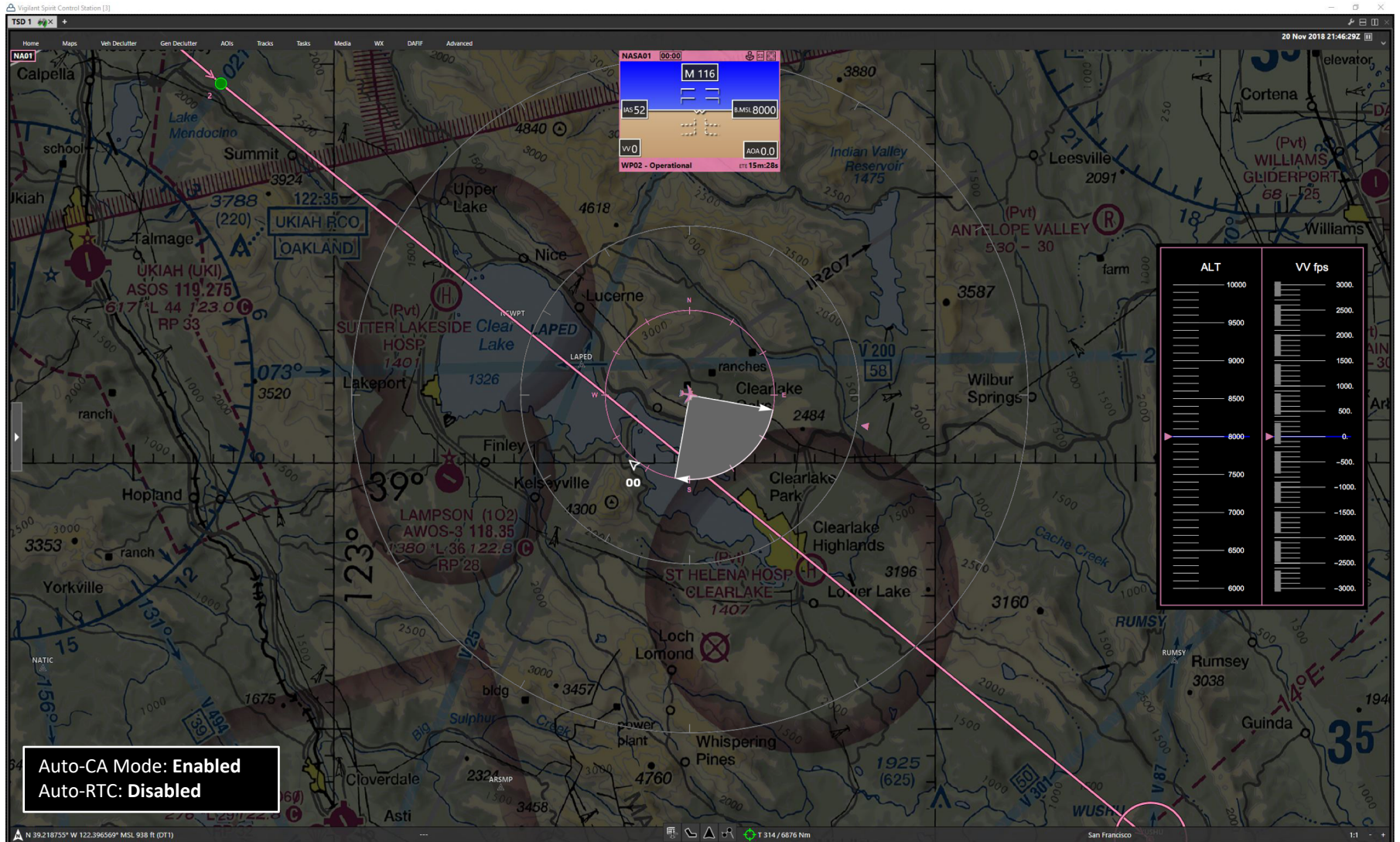


Auto CA Only – Clear of Conflict





Auto CA Only – Manual RTC

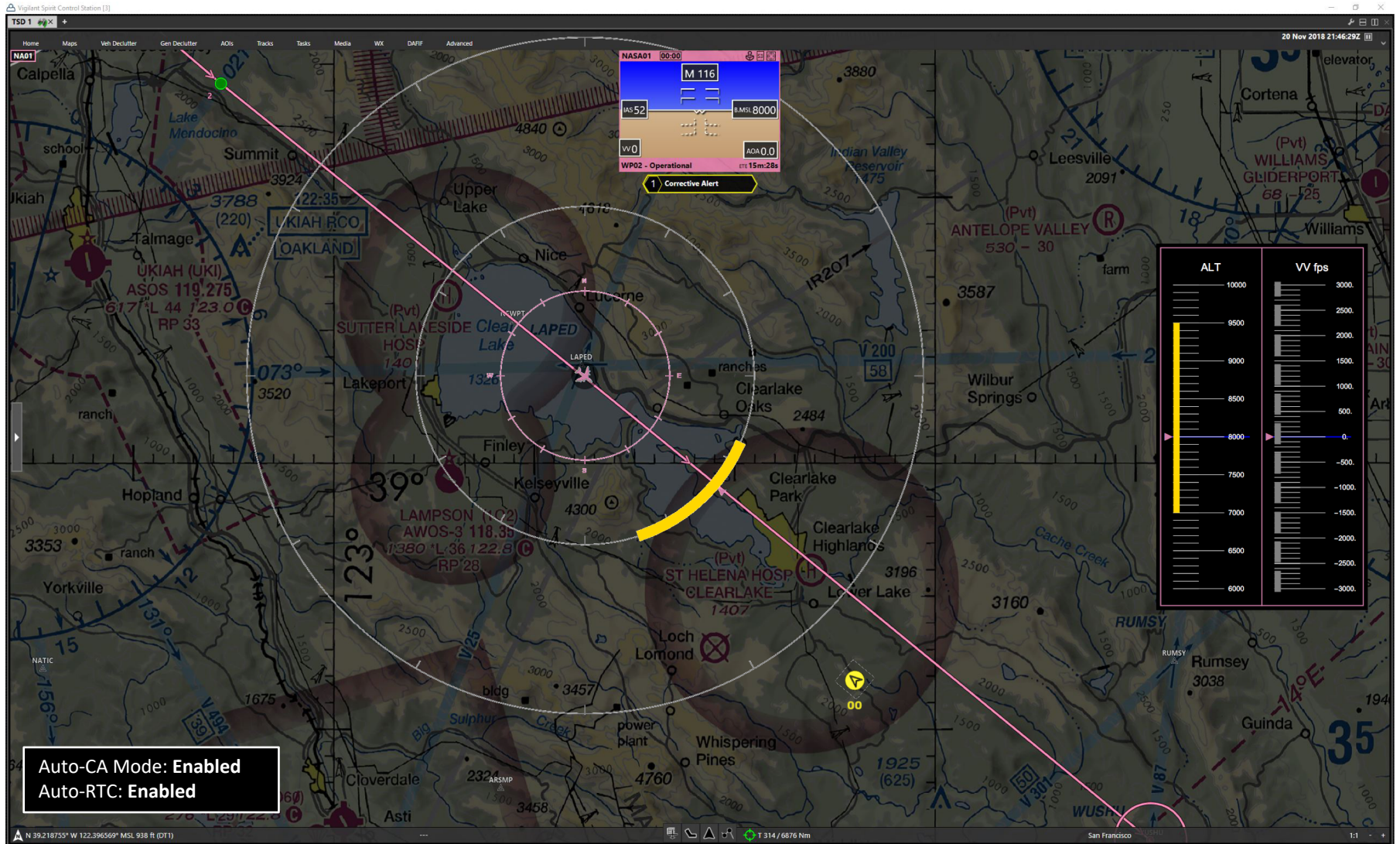




AUTO CA & RTC EXAMPLE

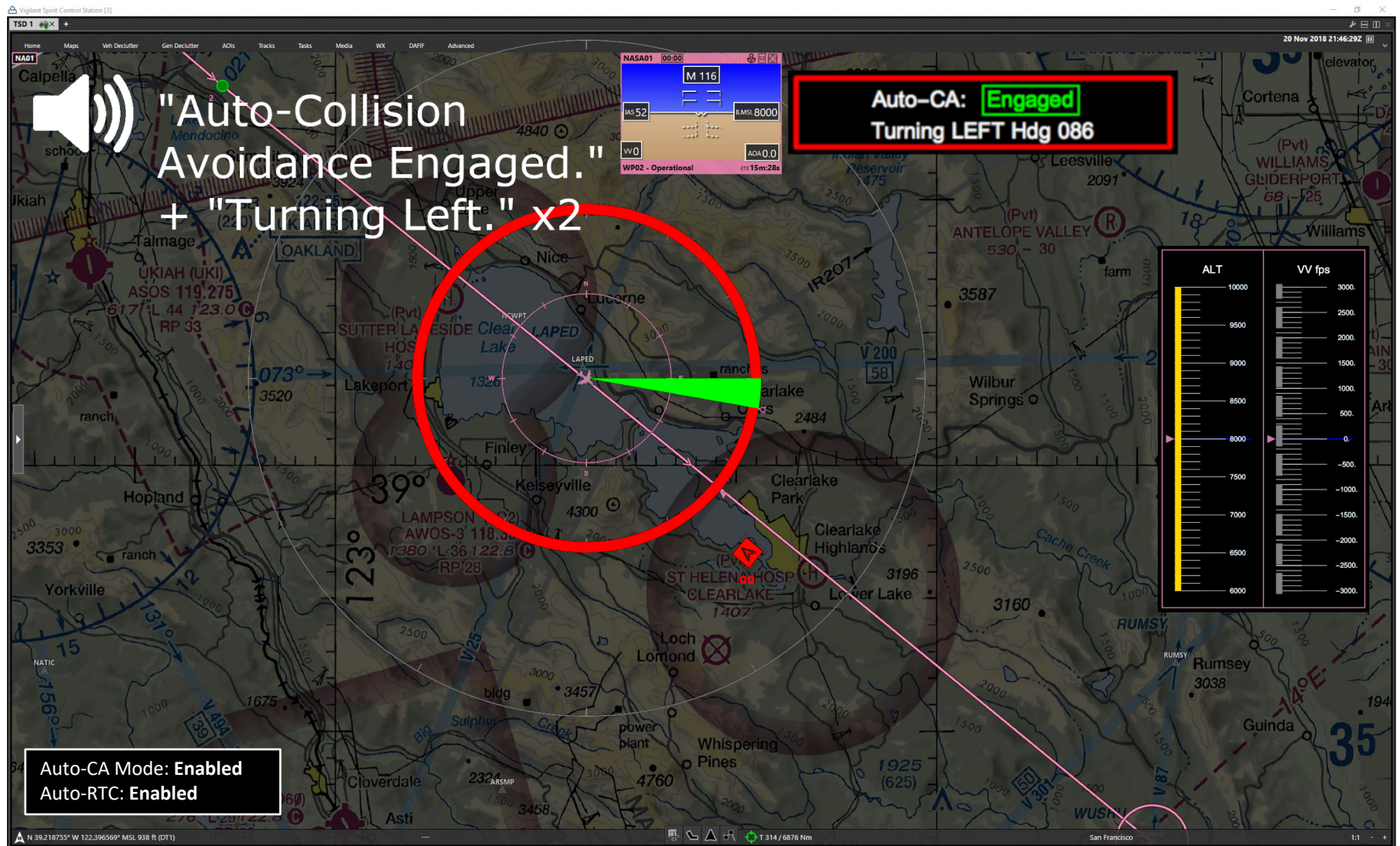


Auto CA & RTC – Prior to RA



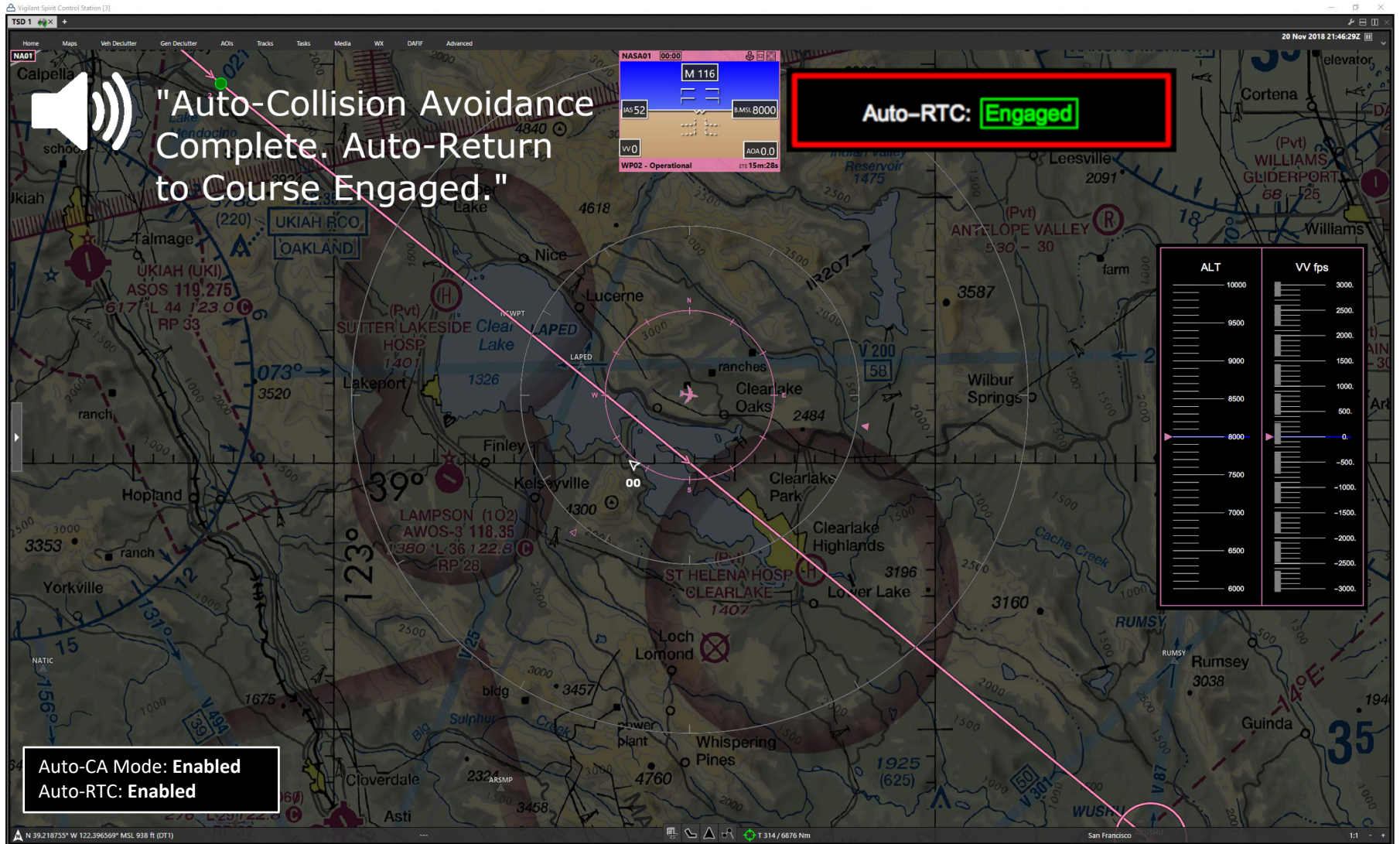


Auto CA Only – RA Issued



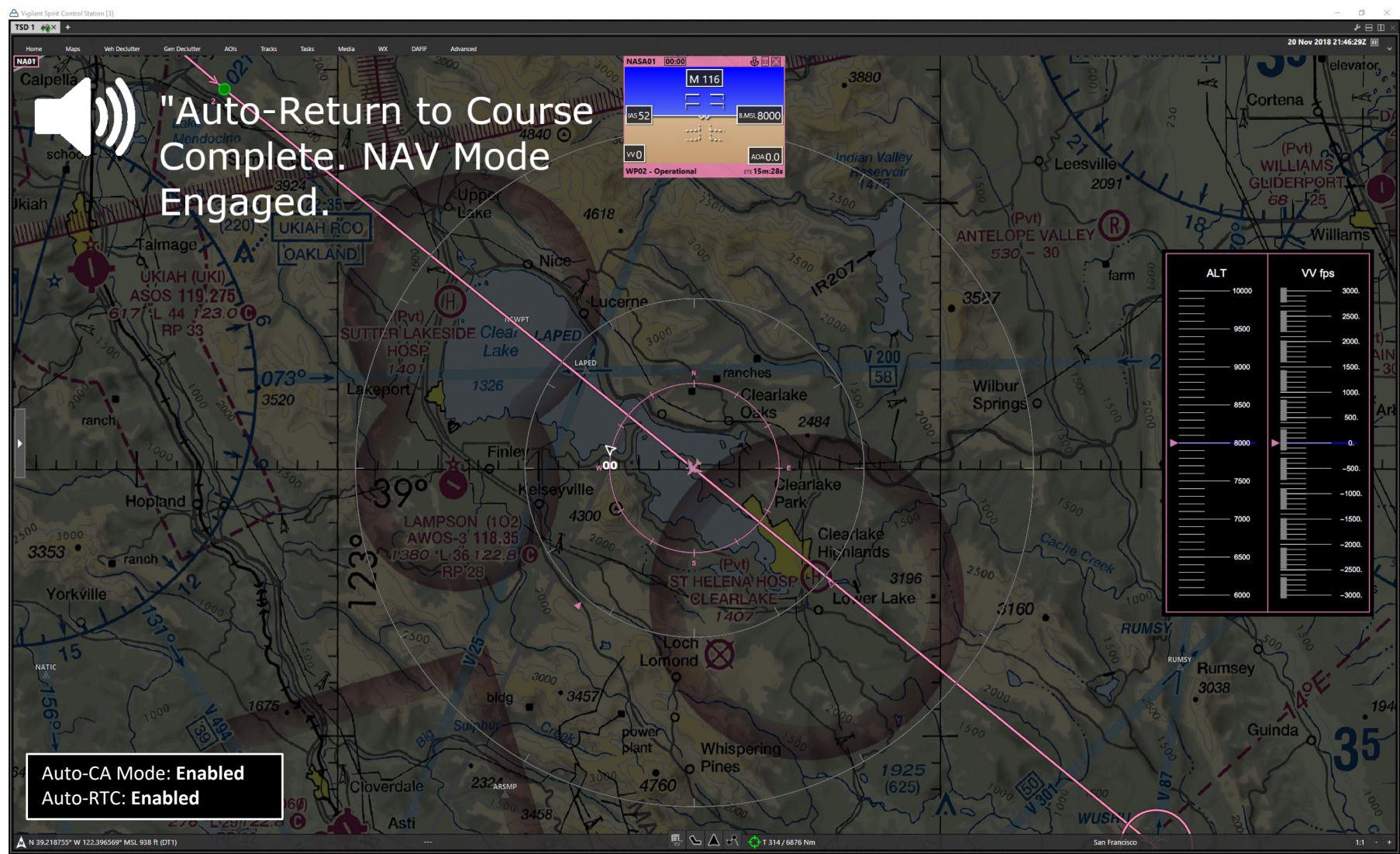


Auto CA & RTC – CoC & Auto RTC





Auto CA & RTC – RTC Complete





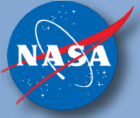
Part 2 Experimental Design

- Dependent Variables
 - Compliance rate
 - Manual condition: did the participant maneuver for traffic in accordance with the presented RA?
 - Auto CA: did the participant override the automation?
 - Reliance
 - Did the participant override the automation when it failed?
 - How long did it take the participant to override the automation?
 - Subjective ratings
 - Workload (NASA TLX)
 - Post-Trial & Post-Sim Questionnaires
 - Post-Sim Debrief (open-ended)
 - Feedback on automation implementation and areas for improvement



Part 2 Hypotheses

- Research Question
 - How does level of automation affect pilot acceptance and reliance on ACAS Xu RAs?
 - How does automation failure affect pilot response to ACAS Xu guidance?
 - Outside of cases of automation failure, when do pilots disengage auto responses?
- Expected Outcome
 - Pilots will be comfortable in allowing ACAS Xu to auto-execute CA and RTC.
 - Pilots will be relatively slow in noticing instances of automation failure.



PARTS 1 AND 2 TEST SETUP



Facilities & Resources

- Human System Integration team
- Facilities: HAT Lab, N-262 Rms. 243
- Ground Control Station
 - Vigilant Spirit Control Station
 - Custom artificial ACAS Xu RA injection tool
 - Allows researcher to specify type and timing of "canned" RAs
 - Have coordinated with Xu team members to best approximate genuine Xu RAs
- Note: the engineering analysis does not include pseudopilots or air traffic controllers



Test Setup

Part 1

- 5 experimental participants
 - Private pilots with TCAS II experience
- Four experimental trials (45 minutes each)
 - Counter-balance two RAs of each type (e.g., horizontal-only, blended-simultaneous) and two non-RA intruders
- Pilot task: comply with RAs

Ownship configuration (Part 1 and 2)

- Generic MQ-9 model
- Cruise speed: 110 KTAS
- Climb/descent rate: 1,000 fpm

Part 2

- 5 experimental participants
 - UAS active duty
- Three experimental trials (45 minutes each)
 - Counter-balance two RAs of each type (e.g., horizontal-only, blended-simultaneous) and two non-RA intruders
- Pilot task: comply with RAs and manage automation





Schedule

- ✓ Experimental Design: NOV 2018 – JAN 2019
- ✓ Initial Software Installation + Tests: NOV 2018 – FEB 2019
- ✓ Scenario Design: NOV 2018 – JAN 2019
- ✓ Programming: NOV 2018 – FEB 2019
- Recruitment: DEC 2018 – FEB 2019
- Shakedown Tests: MAR 4, 2019 – MAR 8, 2019
- ☐ Data Collection:
 - MAR 11 – 15, 2019 (Part 1, 5 participants)
 - MAR 25 – 29, 2019 (Part 2, 5 participants)
- ☐ Data Analysis: MAR 18, 2019 – APR 19, 2019
- ☐ Data Reporting: MAY 2019



Planned Products

- Experiment Reports
 - UAS-NAS Project Outbrief
 - SC-228/147 Brief
 - Conference Proceedings Paper
- Apply lessons learned to future efforts
 - Will implement display concepts refined in this mini-HITL in ACAS Xu Full Mission HITL
 - Will directly inform automation and display, alerting, and guidance requirements for SC-288.



Questions?

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